Mobile Multi-Media Communications - Major Research Areas

*MoMuC-2 Workshop Repor*t

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Summary

At the MoMuC-2 workshop over 70 papers were presented on the network and practical service aspects of mobile multi-media communications. They showed the importance of current and emerging areas of research in the field. Many, like the source coding challenges for voice, audio and video are apparent, but more obscure aspects of system design such as air interface issues were also considered. Papers were presented on the unique properties of spread spectrum in support of multi-media, and on adaptive antennae, adaptive equalisation, and linear radio techniques in their provision of high capacity and high integrity communications for multi-media. On the architecture side, the different approaches to applications on the campus or in the wide area were considered, where the optimal location of the mobility management and processing intelligence in the network was under question.

Introduction

The second international workshop on mobile multi-media communications was held in Bristol in April 1995. There were a wide variety of papers from early applications to advanced air interface techniques designed to support multi-media traffic. This review will look at the workshop and comment on significant areas of focus and developments.

The market for mobile multi-media is today in its infancy and technology providers, operators, and users wait for the great mystery to be revealed. Indeed many would claim this to be the search for "the killer application" and once we know what it is, the market will blossom. This is undoubtedly a simplistic view and ignores the enormous efforts that must be put in to solve technical problems. As these challenges are resolved, different types of service will become feasible. These were illustrated in a session on the intelligent campus and the virtual university where the Berkeley InfoPad [1] and Walkstation [2] projects and material on virtual classrooms from Waseda University [3] were presented. Complementary to these application level architectural papers were practical experimental and development papers exploring issues that must be resolved to ensure a pervasive service [4,5]. Taking a higher level view were papers on the network level architectural considerations [6,7,8].

InfoPad and Walkstation

The InfoPad and Walkstation projects investigate key architectural aspects of future mobile multi-media architectures. InfoPad utilizes a high compute power, server based architecture with minimum local functionality mobile units [1]. The mobiles are optimized for low power consumption and since they are analogous to the X-terminal of the future, need only a screen, input device and communications port. Communications are envisioned to be by radio. A number of air interfaces are being considered/used prior to more aggressive moves into 1.5V 1.2 micron CMOS CDMA radios and ultimately to the use of mmWave bands.

Walkstation has a longer history with roots in the Columbia Student Electronic Notebook. The key element is the mobility architecture which depends on a mobile Internet router [2]. This implies, but does not necessitate, the mobile client to be a computer in its own right. Hence the mobile can be based on any portable PC platform. Unlike InfoPad, the intelligence for an application resides in the user's client device and any servers it may choose to use. Central to Walkstation is the concentration of the mobility functions in a combined network router/radio unit that is carried by the mobile user. This type of platform with its' standard IP communications base can then benefit from related work in real-time multi-media traffic on the Internet. The effective combination of mobile IP and multi-cast IP, for real-time multi-media services, is not trivial and has resulted in an innovative proposal for a protocol-independent multi-cast routing scheme [9].

Services and Applications

Various papers on applications were presented including work from the EC Drive program which can use the data services offered by GSM. This is a good example of directed data services enhancing voice communications in the near future [10]. Other papers described trials of GSM data services indicating that GSM data offers a reliable cellular data service which can be used for a variety of purposes [4,5,11,12]. Practical considerations of their impact on business re-engineering indicate that significant problems may exist far from the basic GSM service. For example, PSTN modem interworking and set-up times were identified as critical issues, whereas effective operation

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of the GSM SMS and transparent fax service were reported.

The basic GSM data services of short message service, fax and data are soon to be extended with a packet mode service [13,14]. Whereas this is built into the network, a simpler overlay system is available for existing AMPS systems, CDPD [15].

With additional material on PDC data services [17] it is clear that the fundamental challenges of reformatting a data service from the air interface onto modems on the fixed network can be solved. With digital cellular systems like GSM and PDC there is a basic multi-media capability of voice and modem speed data. The data services are not perfect but the limitations can be resolved by good application and network protocol design. It is interesting to note that, in this area the problems encountered are ones where academic contributions are rare. Hopefully, in the development of new services like GRPS, these network issues will be fully considered.

A longer term issue concerns wireless interfaces for ATM. This is a tough challenge with few people even understanding the complexities of the problem. At first sight it may seem that packing ATM cells for transmission over radio is reasonably straightforward. However there are many difficulties in protocol design at the MAC layer, data-link layer and in the signalling and control. Two big issues are quality of service and mobility management. It is difficult to see how wired quality of service guarantees will be maintained over a less reliable and shared radio medium. Handover in ATM was considered in [20] with a problem analysis and proposed methods for handover where there was prior knowledge and also instants when there was no prior knowledge. A prototype on the Cambridge Fairisle ATM switch should produce interesting results. One system level proposal made in [18] could form the foundations for detailed work on the performance of the protocols etc. It would be interesting to see if the methodology, proposed by Sethu, Goodman and Yates[19], to model multi-media MAC protocols and then simulate their performance could be used in this case [19].

Further future thinking on service provision was seen in the main European program for mobile multi-media, MONET [21]. This considered the important, and often forgotten area, of architectures for new networks and in the case of MONET for UMTS, the successor to second generation systems like GSM and DECT.

Alternative methods for the provision of multi-media services using the Digital Audio Broadcasting system were proposed in [16]. In this case various types of information including still pictures could be transmitted to the mobile and synchronized with an audio channel.

Security

For any personal communications system to be trusted a wide range of security services must be provided. Already GSM supports authentication and confidentiality services over the air interface but new multi-media capable third generation systems present new challenges. A report on the activities of the UK DTI/EPSRC LINK program 3GS3 considered the security features that would be required in UMTS and how these would be provided [22]. Key in this list are the requirements for mutual authentication and end-to-end secure services. Although these services can be provided in a number of ways, the art is to find an elegant, manageable, and computationally economic process.

Wireless LANs

The use of wireless LANs for mobile multi-media on a campus was considered. Various technology solutions were considered from the very localised hot spot communications technologies possible with IRDA standard infra-red communications [23], to >10Mb/s radio solutions such as HIPERLAN [24]. These systems permit two different communication models at two different cost points.

Infra-red is a very economic solution for walk-up ad-hoc networking and, as was demonstrated, many of the difficult addressing concepts never have to be resolved because you can simply point and shoot at the peripheral device you wish to use. The short range of the system is used to great advantage in solving a difficult network management problem.

HIPERLAN is one of the first radio air interfaces designed to support multimedia traffic whether it is delay or integrity constrained [24]. HIPERLAN can provide Ethernet like communication speeds over distances of around 50m. This comes at the cost of more complex technology in the radios and more elaborate MAC protocols for resource sharing. Technically simpler radio solutions are available [25] but they lose out on performance.

The design of MAC protocols for wireless LANs has been the focus of much research. Most standards have adopted variants of CSMA which is used to great effect in wired LANs such as Ethernet. There are however difficulties in carrier sensing in a radio environment. This causes collisions and unnecessary deferrals. The impact of these effects on packet delay

were investigated in [26] for CSMA and ALOHA schemes with simple propagation models.

Source coding

Source coding for mobile, with wide variations in fidelity, can be categorised as follows; voice, audio and video. Voice and audio are treated separately due to different coding schemes that can be employed for speech and non speech sources. In both cases the drive is to achieve good enough fidelity and yet decrease the bit rate, minimize the delay and improve the robustness to transmission errors. Specific codec designs were presented including the new VSELP proposal for the GSM half rate codec, which performs almost as well as the full rate codec [27]. The presenter noted that a workable codec is available now. The future deployment of this codec clearly depends on the market. Other types of codec were presented including ideas for codecs operating at hundreds of bits/s, multi-rate codecs and high quality low latency 'wideband' codecs [28,29,30].

Significant work was presented by researchers from the University of Southampton, who under the direction of Hanzo are looking at a wider, more systems oriented approach [31,32]. This work attempts to tie together the codec design with the MAC and PHY designs taking into account the variable nature of the channel. The work gives a grasp on the bigger system picture and shows the value of each design decision rather than focusing on the individual merits of one element of a system.

Another key systems aspect was the need to operate speech and video over the same limited throughput channel. This represents a challenge to design co-operative voice and speech codecs that can make the very best use of the available bandwidth [33]. A key element in any coder design is the robustness of the system. This area was specifically addressed for image and video coding [34]. An interesting extension of this would be to look at the robustness of voice and video coding.

The search for low bit rate video coding continues. Practical system level proposals which included the effects of the radio link design were made alongside more fundamental work on fractal coders [35,36,37]. MPEG-4, although a major discussion point was only covered by one paper that proposed a dynamic adaptive management scheme for the programming of a terminal [38].

Spread Spectrum

Two key papers on the use of CDMA for third generation cellular radio were presented side by side. The UK DTI/EPSRC LINK CDMA consortium presented details of their latest work in building a small scale demonstrator [39]. This was a very timely paper since prototyping is underway and the paper provided key implementation details of the down-link. Alongside this was a system level description of the NTT DoCoMo DS-CDMA test bed [40]. Both systems use much higher chipping rates than those used in IS95 and follow the conclusions of the invited paper on propagation aspects for CDMA by Beach [41]. The increased chipping rate of the proposed systems allows better opportunity for delay diversity, less signal strength variations and ultimately better power control. This is in direct trade off for the increased complexity of the radio sub system.

One of the aspects to be targeted in the UK DTI/EPSRC LINK project is the performance enhancement provided by macroscopic diversity or soft handover. The potential of soft handover in CDMA was investigated through propagation measurements in [42]. The degree of soft handover provision is an important aspect in network planning, as it can significantly improve performance but places a greater strain on the infrastructure. This was illustrated using network planning tools in [43].

The ability of CDMA to support multiple variable bit rate sources in a flexible way was demonstrated in [44]. This is one major advantage that CDMA has over its competitors. Variable bit rates cannot easily be supported in such a flexible manner with TDMA or FDMA.

Papers were also presented on the use of CDMA in other applications such as robust image transmission [45] and to improve capture in packet radio networks [46].

Adaptive Antennae

Several papers were presented on the subject of adaptive antennae for third generation cellular systems. A general introduction to the use of adaptive antennae in cellular base stations was presented in [47]. This paper outlines the advantages of this technique, on the downlink to confine the radiated energy associated with a mobile to a small volume limiting interference and increasing capacity, and on the uplink to null out interfering and multipath components to further increase performance. This paper described the findings of the trial performed in the RACE TSUNAMI project. The application of the technique in a CDMA system was described in [48]. The specific

problem of direction of arrival estimation was also addressed [49,50]. The use of sectored antennas with MLSE techniques for reduction of multipath was shown to be very effective in work from the University of Kyoto [51].

Adaptive Equalization

Multipath counter measures are required to deliver the necessary high transmission rates for multi-media traffic, in a mobile environment. Equalization has been a popular choice for systems from GSM to IS54. These system components require considerable processing power and hence careful examination of the complexity performance tradeoff for these components is an important aspect of system design. This tradeoff was investigated in [52]. In this paper new architectures and algorithms were proposed. The novel concept of pre-equalization at the base station was introduced in [53]. The beauty of the technique is that the complex signal processing is confined to the base station keeping the mobile simple, cheap and power efficient. There are however many problems in the implementation of the technique; the most important being channel estimation. The results of a trial of the similar but simpler technique of instantaneous adaptive power control were presented in [54]. The technique delivered a significant system performance enhancement.

Linear Radio Techniques

A comprehensive paper on the state of the art in linear radio technology for systems using linear modulation was presented in [55]. The advantages and disadvantages of all linearization schemes were discussed. The advances in amplifier linearization techniques combined with reduced transmit powers have enabled the adoption of linear modulation schemes in a number of new systems. The most notable of those discussed was the Motorola MIRS system, which uses multi-carrier multilevel modulation. This is a significant step in a new direction.

Systems Approach

In the closing panel discussion, there was a number of comments on the missing pieces of research. The workshop had bought together some examples of systems and a number of papers had looked at putting together fundamental technology elements into sub-system modules but there was not a strong theme on overall systems integration and the performance of an entire system. Clearly this is a major opportunity for future research in mobile multi-media.

Conclusion

The workshop format of MoMuC-2 bought together researchers from a very wide variety of backgrounds. This enabled papers of varying depth to be presented side-by-side to provide a wider perspective and viewpoint which was extended by a keynote addresses and also panel sessions [56,57,58]. Mobile multi-media is slowly evolving in the market as the various public and private systems develop and it is hoped that the third dedicated workshop on this important area, provisionally planned for 1997, will be an even greater success.

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